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## SELECTION OF THE BINDER COMPOSITION FOR ABRASIVE ELECTROCORUNDUM INSTRUMENTS

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The properties of ceramic binders used in the production of electrocorundum abrasive instruments are discussed. The methods for studying the properties of ceramic binders are analyzed, including the methods making it possible to study the process of sintering of the binder components and the electrocorundum grains and the formation of the binder structure and the contact zone between the binder and the electrocorundum.

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Abrasive electrocorundum instruments based on ceramic binders are porous materials consisting of electrocorundum grains connected by bridges of the binding material (35 – 55 vol.%). The physicomechanical properties of the instrument, including the properties responsible for the service parameters, largely depend on the properties of the binder. The main principles of the phase composition of binders, the type of their connection to abrasive grains, and the relationship of these parameters to the mechanical and service properties of instruments were considered earlier [1 – 4].

The initial components of ceramic binders are refractory or low-melting clays, feldspar, talc, quartz, and sodium silicate introduced into the mixture as a temporary binder and a moistening agent. The binders are multicomponent aluminosilicate systems with the following ratio of oxides: 15 – 20 %  $\text{Al}_2\text{O}_3$ , 70 – 75%  $\text{SiO}_2$ , remainder  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{CaO}$ , and  $\text{MgO}$ . In the course of firing an instrument, the ceramic binder components react with each other and with electrocorundum and form a vitreous interlayer. The determination of the  $\text{Al}_2\text{O}_3$  content in the initial binder compositions after firing using the chemical analysis method indicated that the  $\text{Al}_2\text{O}_3$  content increases to 25 – 30%. The degree of dissolution of electrocorundum depends on the firing temperature and the content of the alkaline oxides and  $\text{MgO}$  in the binder. The dissolution of electrocorundum apparently proceeds according to the following scheme: sodium silicate dissolves  $\text{Al}_2\text{O}_3$ ; as the latter dissolves, the viscosity of the liquid phase at the site of contact between the electrocorundum grains and the binder increases, and diffusion (dissolution) of  $\text{Al}_2\text{O}_3$  is impeded. Next the remaining components of the binder fuse and the crystalline phases are formed: mullite, cordierite, and spinel.

Studies of the variations of the chemical composition of the binder depending on the treatment temperature established that corundum reacts with the binder during the temperature rise, but during exposure at the maximum firing temperature the  $\text{Al}_2\text{O}_3$  content virtually does not change. It was observed that the firing conditions of several binders with different sintering temperatures coincided, presumably due to the modification of the composition of the binder in the course of its reaction with electrocorundum.

In the course of firing an instrument, the binder forms glass bridges with the residual crystalline inclusions or with new crystalline formations. It is noted that the strength of abrasive composites is higher if a composition not prone to crystallization emerges in firing, or if crystallization is restricted by the contact formation of minerals without disturbing the general vitreous structure of the binder.

Abrasive instruments are not easy to analyze due to their heterogeneous structure and composition. Special methods have been developed for microscopic analysis of abrasive crock taking into account the specifics of abrasive instrument [3, 4]. They were used in selecting an optimum firing temperature for abrasive instruments. An analysis of the binder in insufficiently fired samples revealed insignificant formations of plagioclase, anatase, and fused cracked quartz grains of different sizes, which did not have enough time to fully dissolve in the melt. The binder bridges with inclusions of the crystalline phases exhibited cracks, which were the reason for the low strength of the wheels (or the “dull sound” of the wheels).

A microscopic analysis of overroasted wheels indicated that the binder bridges in this case as well contained new crystalline phases, namely, plagioclase, anatase, and magnetite. The latter is formed in the reaction with the slag components of the corundum. The contact zones of the binder and

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the corundum grains had numerous microcracks, which accounted for the dull sound of the overroasted wheels. The content of the binder in these wheels was nearly doubled, which pointed to considerable dissolution of the electrocorundum grains and their ovalizing.

In an electrocorundum instrument with an operating speed of grinding over 35 m/sec, the tearing strength of abrasive crock should be increased at least 1.5 times. The solution of this problem implied the development of a binder providing for a high strength of fixation of electrocorundum grains. Special attention was paid to the development of a technology for binder production: the processes of milling and mixing of components, the determination of the fineness of milling, and the choice of material sources for the production of standardized ceramic binder compositions.

Boron-bearing compositions were investigated. Boron was introduced via boron-containing minerals (hydroboracite, ascharite) and via borax. However, these methods proved inefficient. In searching for homogeneous binders, technologists frequently tried glass as a binder component, in particular, window glass. The use of window glass failed to produce a strong binder for abrasive instrument. Fritting of binders for electrocorundum instrument is an inefficient technique since in this case one has to eliminate clay, which is a binder component imparting mechanical strength to nonfired abrasive products [5 – 7].

An efficient method for obtaining high-quality abrasive instruments is the introduction of aluminoborosilicate glass into a binder composition. This made it possible to lower the firing temperature to 1220 – 1250°C and implement the production of high-strength abrasive instrument for grinding machines with a working speed of 50 – 60 m/sec. The bridges of the binding material in the instrument are represented by glass with insignificant inclusions of residual quartz and mullite crystals. The mechanic strength of the instrument exceeded the strength of an instrument based on binders consisting only of argillaceous and feldspar minerals and enabled it to operate at a working speed of 50 m/sec.

The practical experience in developing wear-resistant and edge-durable instrument shows that the only way to obtain such instrument is to use vitreous binders. Such binders can be obtained if in addition to the mineral components (clay or kaolin and feldspar) one adds glasses which decrease the temperature of vitrification of the binder components in firing of the instrument [8, 9]. The best strength and service parameters are registered in abrasive instrument based on lithium-aluminoborosilicate ceramic binders. With a virtually equal content of  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$ , it is possible to almost totally prevent crystallization in the zone of contact between the electrocorundum grains and the binder.

Studies comparing the mechanical properties and the structure of the binder bridges that differ in all their components also corroborated the necessity of using compositions which after firing produce binder bridges in the form of homogeneous glass with no crystal inclusions, neither residual

crystals nor new crystalline formations [9]. Monolithic vitreous bridges ensure a high volume porosity of the instrument and the possibility of increasing the volume content of the abrasive component, which provides for better treatment conditions.

The problem of developing highly efficient binders is topical now in view of changing sources of raw materials, and an additional requirement is reducing the electricity consumption in producing electrocorundum abrasive instrument.

In spite of the extensive research directed to improvement of the compositions of ceramic binders, there are no data on the relationship between the chemical and mineralogical composition of a binder and the conditions of firing of the instrument, and no updated criteria for evaluating the compatibility of the components. According to the current technical standards, the main criteria for evaluating a binder is its heat resistance and chemical composition. These parameters are insufficient in developing binders based on new mineral components or in choosing a binder composition with a low firing temperature. Therefore, it is necessary to clarify the range of requirements imposed on the physicochemical properties of binders of electrocorundum instruments and their components.

The present paper analyzes the results of dilatometric measurements and the data of differential scanning calorimetry (DSC) of binders with different compositions and a different glass content for the purpose of establishing criteria for the development or improvement of ceramic binder compositions.

The dilatometric measurements made it possible to obtain plots for the temperature dependence of linear expansion and compression and differential dilatometric curves characterizing the physical meaning of the processes occurring in the binder in firing an instrument. The dilatometric curves were used to determine the temperature interval of sintering of the components to the point of maximum shrinkage, and the differential curves served to register the phase transformations in kaolinite in the course of heating and sintering of the components.

The DSC method makes it possible to determine the thermodynamic parameters of materials (heat capacity and its variations) and also the kinetic parameters of processes under programmed temperature variation [10]. The analysis of binders using the DSC method made it possible to estimate the softening temperature of the binders and the heat capacity jump within the softening interval. The relaxation capacity of the binder composition was determined based on the surface area of the endothermic peaks near the softening temperature.

The binder compositions converted to the main oxides are shown in Table 1. The kaolin content of 30% is equal in all compositions.

The dilatometric measurements (Table 2) indicated that the exothermic effect that is typical for metakaolinite transformation at 920 – 1050°C in a clay-feldspar composition occurs in the interval of 755 – 950°C. An introduction of

TABLE 1

Binder	Content, %, of glass			Weight content in binder, %							Heat resistance, °C
	1	BG	VL	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	B <sub>2</sub> O <sub>3</sub>	Na <sub>2</sub> O	K <sub>2</sub> O	CaO, MgO	Li <sub>2</sub> O	
300	—	—	—	65.1	23.9	—	2.2	7.0	1.8	—	1350
320	20	—	—	65.0	21.1	3.6	3.5	2.8	6.5	0.6	1230
330	30	—	—	65.6	18.7	6.3	6.2	2.7	4.5	0.6	1150
404	40	—	—	63.0	18.5	7.4	—	—	—	—	1150
BG	—	30	—	63.0	18.2	2.5	5.5	5.3	2.1	0.9	950
VL	—	—	30	64.0	19.0	5.3	2.5	5.8	1.4	1.3	950

TABLE 2

Binder	First exothermic peak (transformation of metakaolinite), °C			Second exothermic peak (sintering), °C		
	starting temperature of crystallization	end temperature of crystallization	temperature interval of crystallization	starting temperature of crystallization	end temperature of crystallization	temperature interval of crystallization
300	755	948	193	948	1143	195
320	730	903	173	903	1127	224
330	710	915	215	915	1084	169
404	664	886	222	886	1060	174
BG	653	797	144	797	922	125
VL	650	810	160	810	928	118

glass 1 to the composition decreases as well the temperature of the exothermic peak: with the content of glass 1 equal to 40%, the effect of metakaolinite transformation is registered in the temperature interval of 665 – 885°C, and the interval of the first exothermic peak expands. The second exothermic effect correlating to the sintering of the components and the formation of mullite in a clay-feldspar composition now occurs in the interval 950 – 1150°C; the introduction of glass 1 lowers the sintering temperature by 50 – 60°C. The liquid phase in the binders containing glass 1 arises at a temperature of 1140 – 1160°C. The temperature interval of shrinkage of the binders determined with a horizontal dilatometer correlates with the interval of the second exothermic effect. The heat resistance of the binders based on glass 1 decreases as the content of glass increases. The heat resistance of binders 330 and 404 was rather close, and the difference in their temperature intervals of sintering was more perceptible.

Replacement of glass 1 with lower-melting glasses BG and VL results in a significant decrease in the temperature of the exothermic effects. The first exothermic effect is observed within a temperature interval of 655 – 820°C, and the sintering interval shifts by about 100°C and becomes narrower. In the case of a clay-feldspar binder this interval amounts to 200°C, and in the case of lower-melting compositions it is 145 – 160°C.

The DSC method was used to investigate fired samples of binders and composites. The results of studying binders and electrocorundum – binder composites with the ratio of the components close to their actual ratio in an instrument indicated the following. Binders with 20 and 30% of glass 1

have a similar softening interval of 687°C but differ in the magnitude of the heat capacity jump, which influences the shrinkage of samples fired in the same conditions. The shrinkage is higher in samples with 30% glass content. A comparison of two low-melting binders BG and VL having close heat resistance values (950°C) revealed their significant difference. Glass BG has a lower softening temperature and a wider softening interval, and its heat capacity jump is nearly half as much. However, an instrument based on a binder with a high heat capacity jump and a narrow softening interval should exhibit a high degree of shrinkage in solidification and cooling and, therefore, one can expect cracking of articles in cooling.

The performed studies show the possibilities of using thermal analysis to establish the general regularities of the formation of abrasive composites based on ceramic binders.

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